Labor, Liquidity, Learning, Conformity and Smallholder Technology Adoption: The Case of SRI in Madagascar

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Abstract

This paper explores the roles of seasonal labor and liquidity constraints, learning, and social conformity factors in explaining the adoption of a high-yielding, low-external input rice production method in Madagascar, called the System of Rice Intensification (SRI). We present a simple, multi-period model of technology adoption, and then use a dynamic sample selection model to analyze the decisions to adopt, expand and disadopt this method. We find that seasonal liquidity constraints discourage adoption by poorer farmers despite the minimal cash outlays required, while household labor constraints limit the extent of adoption conditional on initial experimentation. Learning effects – both from one's own experience and from exposure to others with experience with the technology – exert significant influence over whether to try the method, the proportion of area planted in it, and whether to continue with it. Finally, we find strong evidence that social conformity considerations affect farmers' discrete decision over whether or not to experiment with the new technology.

Keywords:

Technology adoption, learning, the System of Rice Intensification, conformity

Introduction

Questions of technology adoption lie at the heart of economists' longstanding concerns over economic growth and poverty reduction because advances in human welfare depend on increasing the productivity of existing stocks of land, labor and capital, as growth theory has long emphasized. Yet although significant innovations occur routinely, new technologies diffuse only gradually and incompletely. The dynamics of technology diffusion confound most cross-sectional analysis of adoption patterns, rendering coefficient estimates difficult to interpret, at a minimum, and usually biased and inconsistent (Besley and Case 1993). With the emergence of panel data sets in many countries, there has been a resurgence of empirical work on technology adoption, with a particular focus on the means by which agents learn about new technologies (Besley and Case 1993, Foster and Rosenzweig 1995, Cameron 1999, Conley and Udry 2000).

This paper builds on that literature by studying the adoption of a high yielding, low external input technology, called the System of Rice Intensification (SRI), that has received considerable attention both within and outside of Madagascar, where the method originated (Madeley 2001). Merely by changing a few interrelated agronomic practices – no new seeds or chemical or mechanical inputs are needed – SRI has repeatedly generated stunning increases in crop yields in farmers' fields (Stoop, Uphoff and Kassam 2002). SRI therefore seems ideally suited to the needs of small farmers in a country where rice productivity is extremely low and most farmers are unable to grow enough rice to feed their families (Barrett and Dorosh 1996). But like many promising agricultural technologies in the developing world, its adoption has been disappointing—adoption rates have been low, disadoption rates among adopters have been high, and the method has largely failed to spread spontaneously beyond the communities into which it has been introduced by outside extension agents. This paper explores the roles of seasonal liquidity and family labor constraints, learning, and social conformity factors in explaining the puzzle of poor uptake of such a promising new technology.

Recent models of technology adoption provide a useful starting point for making sense of the SRI experience, but fail to capture all of the relevant factors in the case of SRI. Both Besley and Case (1993) and Cameron (1999) focused on farmers' learning by doing, but do not allow for learning from others or for short-run losses incurred for future benefit due to farmer experimentation. Yet in conversation, Malagasy SRI farmers repeatedly emphasize the importance of instruction in or observation of the new methods as practiced by others and their view of initial SRI trials as a potentially costly experiment. Foster and Rosenzweig (1995) allow for both learning by doing and learning from others and for costly experimentation. But the target input model approach they follow implicitly assumes that adoption is inevitably optimal and therefore that disadoption will never occur. Yet, as we document below, disadoption of SRI has been widespread. Conley and Udry (2000) focus on the social context of learning and emphasize the extreme imprecision of farmers' knowledge of the operational details of others' experience with a new technology. They do not allow for learning by doing, however, which is clearly relevant for the case of SRI as Malagasy SRI farmers frequently mention the importance of time and experience in learning the method. Furthermore, none of the aforementioned studies allow for family labor or seasonal liquidity constraints that can be crucial, not only to Malagasy farmers, but to many farmers throughout the developing world.[1]

Nor does the literature yet incorporate social effects beyond learning. Within rural villages, there often exist significant pressures to conform to behavioral norms established within the community and to the expressed wishes of persons in positions of authority. The former effect can serve as a powerful brake on innovative activity (Akerlof 1980), while the latter may foster innovation when authorities push new methods, creating an opening for charismatic leadership to exert influence on the process of development at the micro level. The challenge in accommodating social conformity effects in a model of technology adoption lies in distinguishing them from social learning effects. We develop a simple method of distinguishing between the two effectively and show that both effects matter in the present case.

The rest of the paper is organized as follows: First we describe the relevant features of SRI and rural Madagascar and provide a brief description of the data. In the absence of panel data, Besley and Case (1993) propose using recall data. This is the approach used here. Next we present a simple, multi-period model of farmer decision-making that allows for binding seasonal liquidity and labor constraints, learning, and social conformity effects. We then use a dynamic sample selection model to test the model econometrically and present our estimation results, which underscore the multifactorial nature of technology adoption patterns in smallholder agriculture.

[1] An earlier literature on smallholder technology adoption placed considerable emphasis on labor and liquidity constraints, along with risk aversion. Feder et al. (1985) offer an especially good survey of the literature to that point in time.

A brief concluding section draws out implications for technology promotion in environments such as rural Madagascar.

Rural Madagascar and the System of Rice Intensification

Madagascar is a smallholder rice economy *par excellence*. Rice accounts for a majority of the nation's cultivated area and of per capita calorie consumption, yet most Malagasy rice farmers do not produce enough rice to feed their families (Barrett and Dorosh 1996, Minten and Zeller 2000). Forced to sell some rice for cash at harvest time, the poorer farmers struggle to find the means to buy rice at higher prices in the months leading up to the harvest, after their rice stocks run out. Seasonal credit is largely unavailable (Zeller 1994), so casual labor for day wages in the rice fields of other farmers is an important coping strategy during the hungry season (Minten and Zeller 2000). Land holdings and income are closely and monotonically related beyond the smallest farm sizes, which are typically home plots cultivated by salaried professional workers (Barrett and Dorosh 1996).

Malagasy smallholders cultivate rice on valley bottoms and terraced hillsides as well as in freshly cleared uplands using methods and seed varieties that have remained largely unchanged for generations. Because of the importance of rice to rural incomes and employment and to national food security, and because of the significant role upland rice cultivation plays in deforestation in Madagascar, intensification of lowland rice production has been a major focus of development interventions in Madagascar for many years. The System of Rice Intensification (SRI), first synthesized by a French missionary priest to Madagascar, Fr. Henri de Laulanie, during the mid-1980s drought, seems almost miraculous. An indigenous nongovernmental organization (NGO), *Association Tefy Saina* (ATS), emerged in the early 1990s to promote SRI in rural Madagascar. Through a combination of practices – chiefly early transplanting and wide spacing of single seedlings, early and regular weeding, and careful water management to dry fields periodically so as to aerate roots during the plants' growth phase – SRI commonly doubles or triples rice yields. In addition, SRI requires no chemical fertilizers, pesticides, or new seed varieties, and the high yields seem to be sustainable thus far and have been replicated since 2000 on test plots and in farmers' fields in Bangladesh, Cambodia, China, Indonesia, the Philippines and Sri Lanka (Stoop et al. 2002, Uphoff 2000a, Uphoff 2000b, Rakotomalala 1997, Association Tefy Saina 1995).

The agronomic practices that comprise SRI are both nontraditional and relatively labor intensive.[2] SRI requires an estimated 29 to 54 percent more labor than traditional methods, and hired workers need to be trained and supervised (and sometimes paid more) to follow these new methods correctly (Joelibarison 2001, Assoiciation Tefy Saina 1995; Rakotomalala 1997). According to Rakotomalala, 62 percent of the extra labor needed for SRI is for weeding and 17 percent for transplanting. Field preparation, especially leveling to facilitate proper water drainage, also takes time, and fields need to be visited daily to check the water level.

Even with the additional labor costs, the returns to labor still seem to far outweigh those of traditional methods. Joelibarison (2001) estimated a 113% increase in net revenue with SRI over traditional methods.[3] Several studies have simultaneously recorded yields for both SRI and non-SRI fields. Three different studies (two of them on-farm) in different regions of Madagascar found average SRI yields of between 6.19 and 6.83 tons/hectare while average yields for traditional methods were between 1.95 and 3.37 (Joelibarison 2001, Rajaonarison 1999, Rakotomalala 1997). Individual farmer SRI yields of over ten tons/hectare have regularly (and credibly) been reported.

Despite SRI's obvious, considerable benefits and intensive ATS extension efforts in certain areas, the casual perception of many observers in the late 1990s was that SRI adoption rates were generally low, that some Malagasy farmers who tried SRI had subsequently disadopted (i.e., stopped using the new technique), and that those who successfully adopted and stayed with the method rarely put more than half of their rice land in SRI. We therefore set out to document and explain SRI adoption patterns among Malagasy rice farmers.

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[2] SRI is nontraditional both in the sense of breaking from customary practice in Malagasy rice systems – an issue we confront in this paper – and in the sense of challenging conventional wisdom within the world's rice production scientific community. Stoop et al. (2002) address this latter issue in detail.

[3] This study compared the labor usage and yields for SRI and traditional methods among farmers practicing both methods simultaneously. The net revenue estimate only includes labor costs, but due to the cost and availability of fertilizers and pesticides, these inputs are rarely used and seed is the only other major cost. The difference in net revenue may actually be underestimated because SRI requires only about 1/5 of the seed used in traditional methods (Joelibarision 2001, Rakotomalala 1997)

The Data

The study was conducted over several months in 2000 in five villages purposively chosen based on past ATS extension presence.[4] Manandona and Anjazafotsy are villages in the central plateau near the city of Antsirabe in the Province of Antananarivo. The other three villages, Ambatovaky, Iambara and Torotosy, are near the Ranomafana National Park in the Province of Fianarantsoa. The former sites are in one of the more fertile and diversified agricultural zones in the country, where agricultural intensification efforts have aimed at income growth and the generation of food surpluses for the cities. The latter three sites are more remote and reflect efforts to promote agricultural intensification as a means to stem unsustainable tropical deforestation associated with traditional, slash-and-burn rice cultivation (*tavy*).

We first used qualitative research methods at the village level, constructing seasonal calendars and enumerating prevailing livelihood strategies so as to get a solid, if only qualitative, command of local wealth, income, labor and liquidity patterns. We then performed a census of all households in each village to assess the evolution of SRI adoption and disadoption over time. The household census provided the sampling frame within which we stratified households at each site into three categories: "adopters" who were currently practicing SRI, "disadopters" who had previously tried SRI but discontinued the practice, and "non-adopters" who had yet to try SRI. Households were randomly drawn from each stratum at each site. We oversampled adopters and disadopters in order to assure sufficient observations. This is a common practice in adoption studies, although few correct for it in subsequent statistical analysis due to lack of knowledge about the true population.[5] However, since we censused all households and were able to reconstruct the rosters of all SRI adopters at each site from ATS records, we can and do make such corrections. Since we know the true population proportion in each stratum, we correct for choice-based sampling in all the econometric results presented here using a weighting variable following the method developed by Manski and Lehrman (1980).

Yield data were not collected due to the timing of the fieldwork and the difficulty in obtaining reliable yield data using farmer recall. Furthermore, if we are primarily interested in disadoption

[4] Details on the survey methodology and copies of the instruments used are available in Moser (2001).
[5] The implication of weighted sampling for a linear regression model is that parameter estimates will be inconsistent if the true parameters in the population differ by category. To correct for this, the data needs to be weighted by the true proportion of the population each category represents at each site (Deaton 1997).

and non-adoption of SRI, only having information on non-SRI yields from the previous season for these groups would not be very useful. However, based on ATS records from previous years, there is no apparent difference in the SRI yields of farmers who would later disadopt and those who continued to practice the method. Furthermore, based on the interviews with disadopters, disappointment with the SRI yield was not a common reason for abandoning the method. The most common problems with SRI cited by disadopters related to time pressures, especially surrounding transplanting and weeding.

Despite the potential yield and profit gains from SRI, we found the percentage of farmers trying SRI to be surprisingly low, just 25 percent (Table 1). Moreover, only 15 percent of farmers were still practicing SRI at the time of the survey, implying an astonishingly high average disadoption rate of 40 percent, although that masks considerable dispersion, from 19 to 100 percent, across the five survey villages. The dynamics of adoption across all five sites from 1993-1999 are presented in Figure 1. When one compares the dynamics of initial SRI adoption (Figure 1) to the adoption of modern, high yielding rice varieties in Asia, as documented by David and Otsuka (1994), one is struck by both the relatively slow rate of adoption over the initial seven years of technology availability and by the high rate of disadoption.

The major source of data used in this paper was a survey of 317 households that included questions on household and farm characteristics, land holdings, SRI use, and problems with and perceptions of SRI. Because income sources, rather than actual measures of income or food stocks, are used in this study, we can only make rather loose, qualitative inferences with regard to liquidity effects. Nonetheless, this method of evaluating and categorizing income sources in each village based on their seasonality and significance using extensive interviews and participatory research provides reliable indicators of household wealth and liquidity.

While the data collected for this survey were collected in a single visit to each respondent household, the farmers were asked to recall total land area, area in SRI and area in off-season crops each year going back to 1993. Given the importance of lowland rice plots to rural Malagasy households, the infrequency of land transactions, and the availability of supporting extension records, these recall data is considered quite reliable.[6] From ATS, we were able to

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[6] In the early 1990s, Madagascar's national agricultural research institute, FOFIFA, compared farmers' reported land area against actual measurements of the same plots in the area of our study and found farmer recall to be extraordinarily accurate on lowland rice areas – albeit not on *tavy* land or upland plots sown in tubers or vegetables.

obtain additional information on the availability of extension and the number of SRI adopters in the population for each site, by year. The farmer recall data and extension records were used to reconstruct a panel data set, an approach first suggested by Besley and Case (1993).

A Model of Farmer Technology Choice

In order to model the decision-making process of Malagasy households realistically, we add three main features to a standard model of intertemporal utility maximization. The first is the dominant role of rice in income and consumption patterns. The second is that we allow for farmer experimentation, expansion or contraction (in the limit, disadoption) of the technology and include a seasonal component to capture the trade-off between current planting-season consumption and rice production. Lastly, we add a social dimension to the model to allow for decisions driven by non-material motives other than profit or consumption.

Each household has an endowment of land (A)[7], family labor (L^T), wealth (W) and education (E) that it deploys to maximize the stream of utility derived from material consumption (C) and the nonmaterial welfare effects of social standing (N).[8] We assume there exist two distinct rice production technologies, SRI and SRT (traditional methods). A farmer must choose the proportion of land to devote to SRI (*a*) and to SRT (1-*a*), as well as the amount of labor to devote to each method, the amount of labor hired in and out, and current period borrowing and savings. Households face a <u>subsistence constraint</u> that in each season k in year t household i must consume at least the minimum amount needed for survival (C^{min}). There are two seasons, a planting season (k=0) and a harvest season (k=1). The usual <u>budget constraint</u> bounds the value of consumption and savings (S) by household total income (Y^T) and borrowing (B) each season. The household faces a <u>borrowing constraint</u>, however, that is an increasing function of its land holdings and wealth. The usual labor time constraint requires that labor time allocated to rice (L^r) and other activities (L^w) not exceed the total family labor available (L^T). The final pieces of the

[7] We focus only on lowlands suitable for rice cultivation. In practice, households often have other types of land available on which they cultivate other crops. But land suitable for rice is basically only planted in rice. So we simplify the model by considering only rice here, dropping other crops into the residual labor use category.
[8] We assume that composite consumption is the numéraire good. Rice prices and wage rates are thus relative to this good.

stylized model involve a standard wealth law of motion and non-negativity constraints on W, B, and L.

Formally, the utility maximization problem described above can be written as:

$$\mathrm{Max}_{L^{SRI}, L^{SRT}, L^{h}, L^{W}, S, B, a} \sum_{t=0}^{\infty} \sum_{k=0}^{1} \delta^{2t+k} U(C_{ikt}, N_{ikt}) \qquad (1)$$

subject to

$$C_{ikt} + S_{ikt} + (1+d)B_{i(1-k)(t+k-1)} \leq Y^{T}_{ik} \qquad \textbf{(i)} \quad \text{Budget Constraint}$$

$$L^{SRI}_{ikt} + L^{SRT}_{ikt} + L^{w}_{ikt} \leq L^{T}_{ikt} \qquad \textbf{(ii)} \quad \text{Seasonal Familiy Labor Constraint}$$

$$C_{ikt} \geq C^{min} \qquad \textbf{(iii)} \quad \text{Seasonal Subsistence Constraint}$$

$$W_{ikt} = W_{i(1-k)(t+k-1)} + S_{ikt} \geq 0 \qquad \textbf{(iv)} \quad \text{Wealth Law of Motion}$$

$$0 \leq B_{ikt} \leq B(A_{ikt}, W_{ikt})$$

with the following variable definitions

$$N_{it} \equiv g(a_{it}, \bar{a}_{j(t-1)}, X_{jt}) \qquad \text{(2) Social Returns}$$

$$Y^{T}_{ikt} \equiv Y^{r}_{ikt} + w_{ikt}(E_{i}, w_{jt}, O_{ikt})L^{w}_{ikt} + B_{ikt} \qquad \text{(3) Income}$$

$$Y^{r}_{ikt} \equiv kp^{r}\left[F^{SRI}(a_{it}, L^{SRI}_{ikt}, L^{h}_{ikt} \mid A_{it}, K_{it}, L^{SRI}_{i(1-k)t}, L^{h}_{i(1-k)t}) + F^{SRT}(a_{it}, L^{SRT}_{ikt}, L^{h}_{ikt} \mid A_{it}, L^{SRT}_{i(1-k)t}, L^{h}_{i(1-k)t})\right] - w_{jkt}L^{h}_{ikt} \qquad \text{(4) Rice Income}$$

$$K_{it} \equiv h\left(\sum_{m=1}^{\infty} a_{i(t-m)}, \sum_{m=1}^{\infty} a_{j(t-m)}, \sum_{m=0}^{\infty} X_{j(t-m)}, E_{i}\right) \qquad \text{(5) Knowledge of SRI}$$

Household income originates from two sources: rice farming and other activities. Rice income equals the value of the amount produced (price times the production from both technologies) minus the labor costs. In order to simplify the model, labor is assumed to be the only cost in rice production, and land and labor are the only inputs.[9] Because the overwhelming majority of land

[9] Rice seed, chemical fertilizer, animal manure and animal traction are other inputs used in production in the survey areas, but in such minimal amounts that land and labor are clearly the ones that matter most for SRI adoption.

in the survey areas was acquired by inheritance and not purchased, land is assumed to be a costless quasi-fixed input into rice production, and is thus treated as a part of the household's endowment.

Revenue from rice production accrues only in the harvest season (k=1), although labor is needed in both seasons. Consequently, farmers incur a planting season loss which must be offset by savings, borrowing, or other earnings—determined at an individual wage rate w that depends on education, prevailing local labor market conditions (summarized by the unskilled agricultural day wage in village j, w_{jt}), and any off-season crop harvest (O_{ikt}) by the household.[10] Binding subsistence and borrowing constraints can therefore prove a crucial determinant of planting season labor allocation for households with low beginning period wealth (and therefore limited savings to draw down or to use as collateral against which they can borrow). Total income (Y^T_{ikt}) and rice income (Y^r_{ikt}) can thus be written as:

SRI output depends not just on the land and labor applied to this method, but also on the farmer's knowledge of how to implement SRI's nontraditional agronomic methods correctly.[11] Knowledge (K) of SRI can be gleaned through multiple sources: the farmer's own previous

$$Y^T_{ikt} \equiv Y^r_{ikt} + w_{ikt}(E_i, w_{jt}, O_{ikt})L^w_{ikt} \tag{6}$$

$$Y^r_{ikt} \equiv kp^r\left[F^{SRI}(a_{it}, L^{SRI}_{ikt}, L^h_{ikt} \middle| A_{it}, K_{it}, L^{SRI}_{i(1-k)t}, L^h_{i(1-k)t} + F^{SRT}(a_{it}, L^{SRT}_{ikt}, L^h_{ikt} \middle| A_{it}, L^{SRT}_{i(1-k)t}, L^h_{i(1-k)t})\right] - w_{jkt}L^h_{ikt} \tag{7}$$

experience with the method (learning by doing), his exposure to extension educators or the experience of other farmers in the community (learning from others), and his education, which may affect the rate at which he learns from these other sources as well as any potential independent effects. The recent literature on the economics of technology adoption has focused heavily on these sorts of learning effects.

An important complicating factor is that the social context within which a farmer makes his adoption choice may have behavioral effects beyond those related to learning about the

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[10] In some areas, households plant rice fields in potatoes, barley or other crops in the dry winter season when rice will not grow. This has the effect of smoothing income over the year and potentially raising the opportunity cost of household labor above prevailing local wage rates.

[11] Knowledge does not appear in the SRT production function because we assume all farmers possess complete knowledge of this method. We do not claim that SRI is more knowledge intensive, but that the transition to SRI from the technology practiced in the villages for generations does require a transfer of knowledge.

technology. In particular, concerns over social status and nonpecuniary penalties associated with deviation from community norms may affect individuals' decisions as much as or more than profit motives (Akerlof 1980, Rogers 1995, Akerlof 1997, Kreps 1997, Platteau 2000, Kevane and Wydick 2001). Especially in traditional societies, the maintenance of community ties is crucial for the survival of both the household and the community. As a result, many cultures exhibit a strong tendency toward conformity to a community norm, to the will of authority figures, or both. In the present case, we allow for either sort of social conformity effect. Like Kevane and Wydick's (2001) model of the effect of social norms on the allocation of women's labor by farmers in Burkina Faso, we take the most recently observed mean level use of SRI in village j, $\hat{a}_{jt}$, as the prevailing time-and-location-specific community norm. We then assume utility is declining in deviation from the norm (equivalently, welfare is increasing in conformity to the community standard). Conformity to established local behavioral norms might thereby discourage innovation.

Conformity to authority may be equally important. In rural Madagascar, outside experts, such as the ATS extension agents, are viewed as authority figures and treated with appropriate respect. Of particular relevance here, households may feel obliged to follow the extension agent's advice, at least at a symbolic level of modest experimentation with the technology being promoted. Of course, if extension agents' only effect were to stimulate "deferential conformity", then once the extension agent left the community, farmers would be expected to revert back to their old practices.

It may be difficult in practice to disentangle social conformity effects from social learning in observational data. For example, the strategic incentive to delay adoption so as to costlessly observe one's neighbors' costly experiments with the new technology (Foster and Rosenzweig 1995) has qualitatively similar effects to conformity to observed local norms. It may likewise be difficult in practice to separate the marginal adoption effects of learning from extension agents from deferential adoption incentives. In the present context, however, we can indeed distinguish between learning from others – be they neighbors or extension agents – and social conformity.

Let K represent a stock of useful knowledge to which one can add but from which one cannot subtract.[12] More precisely, we assume that K is strictly increasing and weakly concave in both cumulative extension presence in the village and in cumulative past SRI experience in the community. Conformity effects, by contrast, relate solely to current social conditions, as reflected in contemporaneous presence of an extension agent in the village, X_{jt}, and the previous period's average SRI use in the community, $\hat{a}_{jt-1}$.[13] [14] This identification strategy necessarily implies that any estimated effect of current extension presence in excess of that of past extension presence must be due to the added influence of conformity to authority effects, and that any estimated effect of past period community average SRI use in excess of that of cumulative past use must be due to social norm conformity effects.[15]

We can now specify the farmer's constrained value function as:

$$\mathrm{Max}_{L^{SRI},L^{SRT},L^{h},S,B,a}\; U(C_{i00}, N_{i00}) + dV(A_{i00}, W_{i00}) \qquad (8)$$

$$\text{s.t. } Y^{r}_{i00} + w_{i00}(E_i,\, w_{j00}, O_{i00})(L^{T}_{i00} - L^{SRI}_{i00} - L^{SRT}_{i00}) - S_{i00} - (1+d)B_{i(1)(-1)} \geq C^{min}$$

$$S_{i00} \geq -W_{i(1)(-1)}$$

$$0 \leq B_{i00} \leq B(A_{i00}, W_{i00})$$

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[12] This is quite different from the target input model employed by Foster and Rosenzweig (1996), where knowledge is embedded in beliefs on an optimal input level, which can vary either up or down.
[13] There is no unambiguously preferable measure of past use of SRI in the community for the purpose of establishing either learning or conformity effects. Is it the mere fact of households trying the technique that matters, or the extent of their use? Are the absolute numbers of adopters the important thing or the relative size of the group of SRI adopters to the broader village population? One could credibly argue for any of these formulations. As a result, in addition to using the area planted (in the preceding year, t-1, or cumulatively through t-2), we also re-estimated the model using instead (a) the number of households using SRI the previous year (t-1) and the total number of farmer years of SRI experience in the community through year t-2, (b) the number of households using SRI in year t-1 and the total number adopting through year t-2, (c) the proportion of households practicing SRI the previous year and the proportional community experience with SRI (total number of farmer years of experience divided by the number of households) through year t-2, and (d) the proportion of households practicing SRI in year t-1 and the proportion of households adopting through year t-2. The qualitative results are very similar across all of the specifications. This gives us some confidence that the findings are robust in these data to inherently arbitrary specification choices.
[14] The past history of use in the community variable likely captures not only learning from others effects in the classic sense of farm managers' observations of others' experience, but also the benefits that accrue from the accumulation of experience with the new methods among the population of casual day laborers who get hired to work the SRI fields. If we had data on hired labor and the laborers' past experience (or not) with SRI, one could in principle distinguish between these two effects. We lack such data.
[15] The weak concavity assumption permits us to identify positive differences as attributable to conformity effects, but negative differences could be due to declining marginal productivity of knowledge.

The labor and budget constraints bind with equality under the assumption of local nonsatiation of preferences, and can therefore be incorporated within the modified seasonal subsistence constraint. The simplified problem now has six choice variables (L^{SRI}, L^{SRT}, L^{h}, B, S, α) and three constraints. Taking the household's choice at the beginning of some rice planting season (k=0), arbitrarily setting the year t=0, we can specify the Lagrangian and derive the first-order necessary conditions (FONCs) to the household's constrained intertemporal welfare maximization problem:

$$\mathcal{L} = U(C_{i00}, N_{i00}) + \delta V(C_{i10}, N_{i10}) + \lambda_1\left(-C_{min} + Y^{r}_{i00} + w_{i00}(\cdot)\left(L^{T}_{i0} - L^{SRI}_{i0} - L^{SRT}_{i0}\right) - S_{i0} - (1+\delta)B_{i1-1} + B_{i00}\right) + \lambda_2\left(W_{i1(-1)} + S_{i00}\right) + \lambda_3\left(B(A_{i1-1}, W_{i1-1}) - B_{i00}\right)$$

$$\mathcal{L}_{L^{SRI}}: \quad -\frac{\partial U(C_{i00}, N_{i00})}{\partial C_{i00}} w_{i00}(\cdot) + \delta \frac{\partial V(C_{i10}, N_{i10})}{\partial C_{i10}} p^{r} \frac{\partial F^{SRI}_{i10}}{\partial L^{SRI}_{i00}} - \lambda_1 w_{i00} \le 0, \ \left(= 0 \text{ if } L^{SRI} > 0\right) \qquad \text{(a)}$$

$$\mathcal{L}_{L^{SRT}}: \quad -\frac{\partial U(C_{i00}, N_{i00})}{\partial C_{i00}} w_{i00}(\cdot) + \delta \frac{\partial V(C_{i10}, N_{i10})}{\partial Y^{T}_{i10}} p^{r} \frac{\partial F^{SRT}_{i10}}{\partial L^{SRT}_{i00}} - \lambda_1 w_{i00}(\cdot) \le 0, \ \left(= 0 \text{ if } L^{SRT} > 0\right) \qquad \text{(b)}$$

$$\mathcal{L}_{L^{h}}: \quad -\frac{\partial U(C_{i00}, N_{i00})}{\partial C_{i00}} w_{j00} + \delta \frac{\partial V(C_{i10}, N_{i10})}{\partial Y^{T}_{i10}} p^{r} \left[\frac{\partial F^{SRI}_{i10}}{\partial L^{h}_{i00}} + \frac{\partial F^{SRT}_{i10}}{\partial L^{h}_{i00}}\right] - \lambda_1 w_{j00} \le 0, \ \left(= 0 \text{ if } L^{h} > 0\right) \qquad \text{(c)}$$

$$\mathcal{L}_{S}: \quad -\frac{\partial U(C_{i00}, N_{i00})}{\partial C_{i00}} + \delta \frac{\partial V(C_{i10}, N_{i10})}{\partial C_{i10}} - \lambda_1 + \lambda_2 = 0 \qquad \text{(d)}$$

$$\mathcal{L}_{B}: \quad \frac{\partial U(C_{i00}, N_{i00})}{\partial C_{i00}} - \delta(1+\delta)\frac{\partial V(C_{i10}, N_{i10})}{\partial C_{i10}} + \lambda_1 - \lambda_3 \le 0, \ \left(= 0 \text{ if } L^{h} > 0\right)$$

$$\mathcal{L}_{A}: \quad \frac{\partial U(C_{i0}, N_{i0})}{N_{i00}} \frac{\partial N_{i00}}{\partial a_{i0}} + \delta \frac{\partial V(C_{i10}, N_{i10})}{\partial C_{i10}} p^{r} \left[\frac{\partial F^{SRI}_{i10}}{\partial a_{i0}} - \frac{\partial F^{SRT}_{i10}}{\partial a_{i0}} + \frac{\partial F^{SRI}_{i10}}{\partial K_{i10}} \frac{\partial K_{i10}}{\partial a_{i00}}\right] \lessgtr 0, \quad \begin{pmatrix} < 0 \text{ if } a = 0 \\ = 0 \text{ if } 0 < a < 1 \\ > 0 \text{ if } a = 1 \end{pmatrix} \qquad \text{(f)}$$

$$\lambda_1\left(-C_{min} + Y^{r}_{i00} + w_{i00}(\cdot)\left(L^{T}_{i0} - L^{SRI}_{i0} - L^{SRT}_{i0}\right) - S_{i0} - (1+\delta)B_{i1-1} + B_{i00}\right) = 0 \qquad \text{(g)}$$

$$\mathcal{L}_{\lambda_1}: \quad \left(W_{i1(-1)} + S_{i00}\right) = 0 \qquad \text{(h)}$$

$$\mathcal{L}_{\lambda_2}: \quad \lambda_3\left(B(A_{i1-1}, W_{i1-1}) - B_{i00}\right) = 0 \qquad \text{(i)}$$

The non-negativity constraints imply that the associated FONCs, L_{L}^{h}, L_{L}^{SRI}, L_{L}^{SRT} and $L_{B,}$ hold with equality when L^h, L^{SRI}, L^{SRT}, and B are greater than zero, respectively. L_a holds with equality when a (0,1). If the subsistence constraint binds, the expression in the parentheses in L_{λ_1} equals zero, otherwise λ_1=0 implying that the subsistence constraint does not affect the household's decisions. The Lagrangian multipliers can be interpreted as follows: λ_1 is the value of reducing the subsistence constraint; λ_2 reflects the value of increasing initial wealth (which increases the amount of dissaving that can occur); and λ_3 represents the value of increasing the household's capacity to borrow, by one unit in each case.

The interpretations of the first three FONCs (a), (b), and (c) are essentially the same. In the current planting season, no immediate benefits are realized from devoting labor to rice. The opportunity cost of forgone current income, and thereby consumption, must be offset by the discounted gains from the extra increment of future harvest. More precisely, the marginal cost of labor must equal the discounted future marginal revenue from the rice harvest. The farmer will not put more labor into rice if its opportunity cost exceeds the additional revenue he will get from that labor. When the subsistence constraint binds (i.e., $\lambda_1>0$), the cost of putting labor into rice during the planting season effectively increases. The marginal costs of L^{SRT} and L^{SRI} are evaluated at the individual wage rate, w_i, but for the marginal cost of L^h (c) the village wage rate, $w_{j,}$ is used. Also for (c), the marginal revenue product is the sum of the marginal products of the two technologies with respect to hired labor times the price of rice.

For FONC (d), current savings cannot be used for consumption today and thus the first term of the derivative represent the marginal utility of foregone consumption. Because greater initial wealth reduces the need to save current income for the future, the shadow value of initial wealth (λ_2) reduces the marginal value of saving current income. This means that the marginal utility of consumption less the shadow value of initial wealth must be equal to the discounted value of future consumption.

The derivative of the Lagrangian with respect to *a* (f) reflects the welfare effects of a change in the proportion of a farmer's area in SRI. The only effect of *a* on planting season utility comes through the social benefits function, and the sign can be either positive or negative. If *a* (0,1), the first expression must equal the discounted future utility derived from a change in *a*. This has two different components: first, the direct change in the marginal productivity of land associated with shifting to SRI, and, second, the indirect marginal productivity effect associated with accumulating knowledge. This difference captures the idea that it can be worth a farmer's while to undertake costly experimentation with the new technique on a portion of his land even when it is not expected to increase current returns.

The FONCs can be combined to yield an estimable, reduced form expression for the farmer's optimal choice of area planted in SRI (*a**) as a function of household level variables – past use of SRI, educational attainment (E), initial wealth (W), other income (O), total land area (A), and discount rate – and community level variables – past and present extension presence (X), past use of SRI in the village, the unskilled agricultural wage rate and rice prices:

$$a_{i00}^* = a\left(\sum_{m=1}^{\infty} \bar{a}_{j(t-m)}, \sum_{m=0}^{\infty} X_{j(t-m)}, \sum_{m=1}^{\infty} a_{i(t-m)}, E_i, W_{i0}, O_{i00}, A_{i00}, w_j, p^r, \boldsymbol{d}\right)$$

Since the extension presence variable is common to all farmers within a given village, it would be perfectly collinear with village-level wages and prices, as well as other agroecological factors (e.g., rainfall, altitude, pest or disease incidence) that might affect technology choice. We therefore omit wages and prices in the estimation reported in the next section. A dummy variable for the farmer's membership in a farmers' organization is included in the estimations. This variable is capturing learning effects because extension agents largely worked through local farmers' organizations once they were in a village. The extension presence variable is not specific to the household, so the farmer organization variable is probably capturing both better access to the extension agent in the village and better flow of information from other farmers. Several variables are used to represent family labor availability—the number of adults and children in the household and the distance to and between rice fields. Because detailed income or consumption data were not collected in this survey, we must rely on dummy variables that are indicators of wealth or poverty. These variables are described in Table 2.

We include year-specific dummy variables to capture intertemporal changes in market and agroecological conditions that are common to all the survey villages. There may be unobserved, household-specific attributes that matter to technology choice (e.g., innovativeness). In this sample, however, educational attainment is constant across periods for each farmer, so education and unobserved household heterogeneity become indistinguishable. Rather than difference away the time-invariant component and thereby lose the information associated with educational attainment – an important variable to hypotheses about learning based explanations of technology adoption – we retain that regressor and caution that interpretation of its coefficient is necessarily complicated by the possibility that it also picks up unobserved, time-invariant, household-level heterogeneity in sample. Finally, assuming households' unobservable discount rate, ä, is strongly correlated with wealth, our data permit direct estimation of the reduced form optimal adoption function.

Econometric Strategy and Estimation Results

Although we are concerned with a farmer's choice of *a* in each period, it may be useful to break this decision into smaller steps. First, a farmer must make the initial, discrete decision as to whether or not to try SRI for the first time in any year prior to which he has never tried the method. Conditional on choosing to try the method, he must then decide how much land to put in SRI. Each year following the initial adoption decision, the farmer must again decide how much land to put in the method, or whether to abandon the practice altogether. These decisions are obviously related, but not necessarily jointly determined.

We therefore employ a sample selection specification to allow the optimal extent choice of *a* to be correlated with but distinct from the initial discrete decision to try SRI. Because we need to use a two-year lag to distinguish between learning from others and social conformity effects, there are five observations for each farmer (1995-1999). In the first stage, we estimate a probit binary choice model. The dependent variable takes on a value of one if the farmer is using or has previously used SRI. Thus once a farmer has tried SRI, the dependent variable remains one for all succeeding years. Once the farmer has tried SRI, we similarly fix the independent variables in each year-specific observation at the values taken in the year of adoption.[16] We use the Probit estimate to compute the inverse Mills ratio (IMR) for each observation in order to control for the probability of having ever adopted SRI when we estimate the second stage, censored regression of *a*, the proportion of cultivated rice area planted in SRI. Rejection of the null hypothesis that the coefficient on the IMR is statistically insignificantly different from zero supports this estimation strategy.

Since a=0 in a considerable number of observations, we use a Tobit specification in the second stage of the sample-selection model to identify the correlates of increased area in SRI. In the Tobit model, zero values (the censored values) capture disadoption, while the values greater than zero are the observed values of the year-specific extent of adoption.[17] One inconvenience of this estimation strategy, however, is that it is difficult to isolate the issue of disadoption, since we cannot easily distinguish between a reduction in area planted in SRI that leads to disadoption and a reduction in extent that retains land in SRI. We therefore supplement the sample selection Tobit estimation with a simple probit model of disadoption conditional on past use of SRI. The variables used both the sample selection Tobit and disadoption probit models are described in Table 2. The column labeled "Choice" refers to the adoption decision (and thus the stage or model) for which the variable is relevant.

The Initial Adoption Decision: Table 3 presents the results for the sample selection model. We first consider the farmer's initial, discrete decision to try SRI. Several factors are plainly at play. Farmer liquidity seems to matter a great deal to the initial adoption decision, as reflected by both the positive and statistically significant coefficients on wealth (total lowland rice area) and stable income source (e.g., salaried employment), and by the large, negative and highly significant coefficient estimate on the agricultural day labor dummy variable. Those who have little lowland to sow in rice wind up being net rice buyers and unless they have an education and skills to secure salaried employment, they must then undertake low paying, unskilled farm work to meet immediate cash needs for food in planting season (Barrett and Dorosh 1996, Minten and Zeller 2000). In the absence of seasonal credit access, labor becomes their means of financing current consumption needs, precluding them from investing added time in more labor-intensive cultivation on their own plots, even if this brings significant yield gains next season.[18] Although our initial research design hypothesized that by smoothing incomes within the year off-season cropping might facilitate adoption, the coefficient on the off-season cropping dummy variable

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[16] Otherwise, the dependent variable would temporally precede the independent variables, causing serious endogeneity problems.

[17] In our sample, a=1 in only 12 of 564 household-and-year-specific observations among the 163 adopter and disadopter farmers (i.e. the household used SRI methods on all its lowland rice fields in a given season). We therefore ignore the potential effects of censoring from above.

[18] Empirically, part of this effect could be due to timing, not just liquidity. If workers have to supply labor at prime planting times and realize they would consequently not enjoy equivalent yield gains from SRI were they to try the method once they were free from their off-farm work responsibilities, mistiming could discourage adoption independent of liquidity concerns.

was both small in magnitude and statistically insignificant.[19] A $\div^2$ test overwhelmingly rejects the joint null hypothesis that liquidity – as proxied by agricultural day labor, stable income and off-season crop income – has no effect on adoption (Table 5). Despite the "low-external input" nature of the technology, the investment needed in labor alone is more than those farmers with poor liquidity can afford, since labor markets are used to obviate the problem of a missing rural financial market.

Liquidity is far from the whole story, however. Learning and social conformity effects clearly matter as well to the initial SRI adoption decision. Learning from others is captured jointly by the extension variables, community history of SRI use, and interactions with other (SRI) farmers through membership in a farmer's organization or personal previous knowledge of another farmer already using SRI. The probability of adoption is significantly increasing in the farmer's educational attainment level, and when he belongs to a farmers' organization that improves access to extension information or knew an SRI user prior to his own initial trial of the method. Extension presence also proves important for the initial adoption decision, probably because SRI is a relatively complex set of practices that must be learned and applied simultaneously. Thus it is not surprising that farmers need to work directly with extension agents the year they adopt. The $\div^2$ test statistic of 732.35 rejects the joint null hypothesis that there is no learning from others. Adding education into the mix increases the test statistic further, to 786.96, underscoring the conventional finding that probability of technology adoption increases with years of schooling completed.

Social effects are reflected in current extension and the past season's community SRI use variables. To distinguish the social effects from the learning effects embodied in those two variables, we test the joint null hypothesis that there is no difference between the coefficients on the current extension presence and cumulative past extension presence variables, nor between the coefficients on the past year's use of SRI by other farmers and the history of SRI use in the

[19] However, when the model is re-estimated using only the two villages in which this method has become increasingly important in recent years (Ambatovaky and Iambara), the coefficient on off-season cropping is positive and statistically significant. The method, which consists of planting crops, such as potatoes, on the rice field in the winter, provides income at the start of the rice-planting season. This provides evidence for a sort of "practices ladder" effect—the adoption of off-season cropping may provide liquidity at a crucial time of year which may later enable farmers to adopt improved rice methods such as SRI. The adoption of off-season cropping is also interesting because we can contrast its adoption to that of SRI. Despite the fact that farmers must purchase seed and fertilizer for off-season cropping, the timing of these purchases (right after the rice harvest) is such that it does not seem to

community variables. The test statistic of 131.33 does offer support for the conjecture that social conformity effects play a significant role in farmers' initial decision over whether or not to try a new technology. The effect seems to exist with respect to both conformity to the social norm, as reflected by the difference between the point estimates for use by other farmers and history of SRI use (10.446 - $^{-}$35.346), and conformity to authority, as reflected in the difference between the point estimates for current extension presence and cumulative extension presence to date (0.824 - $^{-}$0.064).

Interestingly, however, conformity effects appear to matter only to the initial adoption decision. They have statistically insignificant effects on the extent and disadoption decisions. This finding is consistent with Conley and Udry's (2000) observation that Ghanaian farmers' understanding of one another's production patterns is limited to coarse scale, qualitative information and that they know little about the details of each other's performance or practice history. If they are aware primarily of general, qualitative information about others, this effect should play out almost entirely in just the discrete adoption decision rather than in the finer, continuous decision as to the proportion of land to plant in SRI.

The Extent of Adoption Decision: The determinants of the extent of adoption demonstrably differ from those of the discrete initial adoption decision. Not only can we not reject the joint null hypothesis that there are no social conformity effects in the extent choice, we likewise can reject neither the null that educational attainment affects the proportion of land planted in SRI, nor the joint null hypothesis that liquidity has no effect on the extent decision conditional on having tried SRI. Liquidity, education and social effects seem to play a role primarily in screening out those who will or will not ever try with the new technology. Among farmers whose social and financial circumstances permit experimentation, a different set of factors condition the allocation of land across the different technologies.

Learning matters just as much to the extent decision as it does to the initial adoption decision. Yet the mechanism of learning appears different. In particular, learning by doing effects associated with the farmer's cumulative past experience with SRI now exert a strong influence. This result makes sense since most disadopters opt out after one or two years and since one would expect farmers to become more skilled with practice, thereby making the method more

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impede adoption for most farmers. For example, eighty-percent of households in Ambatovaky were practicing the profitable and inducing them to increase their use of it. Other farmers' experience with SRI has no statistically significant effect on the proportion of land cultivated following SRI methods. Current extension presence does have a significant effect, although the significant difference between current and past extension presence suggest that part of this effect may be due to "conformity to authority" effects.

Providing aid (almost always in the form of mechanical weeders) to farmers also positively affects the proportion of land cultivated using SRI, probably because the mechanical weeders reduce the labor costs of weeding. Similarly, the distance between a household's rice plots exerts a significant negative effect on the area cultivated in SRI, which likely captures family labor constraints.[20] The joint effects of labor availability, as captured by the number of adults and children in the household and the distance to (or between) the rice fields, are significant determinants of the extent decision although they had no significant effect on the initial adoption decision.

The Disadoption Decision: Only observations after the farmer's first year of use are included in the disadoption probit model because the issue at hand is whether a farmer continues to use SRI after initial adoption. This leaves 418 observations from the 564 in the second stage of the sample selection model for 163 farmers who had tried the method.[21] Following an approach used in Neill and Lee (2001), the dependent variable "Continue" is a dummy variable that equals one if the farmer continued to use SRI in year t, zero if he did not continue (in other words, if he disadopted). Observations on disadopters beyond the first year for which "Continue"=0 are included in the regression because the farmer could renew his use of SRI.[22] The same explanatory variables are included in this model as in the second stage of the sample selection model. The probit disadoption model accurately predicts 75 percent of actual outcomes correctly.

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method in 1999 and none had disadopted.

[20] The distance between rice fields likely affects family labor constraints in two ways. First, SRI farmers must check the water level daily, while with traditional methods the water level is less important and the fields need not be visited as frequently. A second additional cost to attending to distant fields under SRI would likely arise from an increased cost of supervision of hired labor for SRI. Frisvold's work on the importance of supervision of hired labor for productivity supports this claim (Frisvold 1994). The labor time and effort required by traditional methods are well understood by both the landowners and workers, and less supervision is likely required, while these costs of SRI are less clear (especially in the first several years).

[21] 17 farmers started prior to 1995, so 564 minus 146 first year observations gives us the 418 observations.

[22] Adopting a second time (after disadoption) seems to be quite rare, and there was no re-adoption is this sample.

Unlike the extent decision in the second stage of the sample selection model, education is statistically significant in the disadoption model. Better-educated adopters are more likely to continue with the method, most likely because they have a firmer grasp of the agronomic principles underpinning the complex set of practices that jointly generate such high yields. Labor availability positively affects the probability of continuing with SRI, especially as proxied by receipt of a mechanical weeder and by the number of children in the household.

The biggest effects on the likelihood of disadoption, however, arise from the farmer's own past experience with SRI – farmers with more past experience are far more likely to continue than are those with less past experience – and salaried employment. Although possession of stable income from salaried employment improves household liquidity and thereby increases the likelihood of initial adoption, it also significantly decreases the likelihood that the farmer continues to use SRI. Based on our own observations of the system, it appears that this result reflects experimentation by those with the means to try SRI, within which there is a subset of salaried workers whose off-farm activities generate a high opportunity cost to the time spent in SRI cultivation and supervising and training hired workers in one's SRI plots. As a consequence, these households disadopt SRI.

Concluding Remarks

This paper explores the puzzle of disappointingly low rates of adoption and high rates of disadoption among rice farmers in Madagascar of an extraordinarily promising new technology. By recreating the history of adoption and land use among 317 households in five villages, we were able to explore the multifactorial determinants of technology adoption dynamics in such a setting. Consistent with the longstanding literature, we find strong evidence supporting the hypothesis that farmer liquidity and labor availability matter to farmers' willingness to try new, labor-intensive technologies. And like a more recent literature, we find that learning effects play a major role, not only in farmers' initial decisions to try a new technology, but also in the subsequent decisions as to what proportion of their cultivated area to put into the new method and to whether to continue with it in future years. In sum, liquidity, labor, learning and social conformity effects all matter, albeit to different degrees and with regard to slightly different decisions regarding the use of a technology.

The case of SRI highlights a common problem in rural development: technology adoption is key to improving farmer productivity and household income, but the complexity of the adoption process makes targeting technologies difficult. Even when all the essential elements seem to be present (a low-external input, high-yielding technology, significant training and extension efforts, etc.), the end result can disappoint those responsible for developing and promoting the method. The evidence of a social conformity component to adoption decisions found here suggests that extension and dissemination efforts might be targeted more effectively by taking the social effects into consideration.

The labor-intensive nature of SRI and many other low-external input technologies have long been viewed as a positive characteristic in areas where labor is the main resource of the household (Lee and Ruben 2001), yet the labor requirement is precisely the obstacle to adoption for many poor households with highly seasonal labor and income patterns. Seasonal family labor and liquidity constraints prevent the poorer farmers from taking advantage of SRI. Similar findings concerning the distributionally regressive nature of rice intensification strategies in Madagascar suggest that promoting alternative sources of income among the poorer farmers should be an important part of rural development programs in that country (Minten and Zeller 2000).

Yet, it must also be recognized that although the poorest farmers rarely benefit directly from new technologies, because they tend to cultivate smaller plots, be more risk averse and less likely to interact with extension agents (Feder et al. 1985), they may nonetheless enjoy significant net benefits in their role as hired workers and as net food buyers. If bigger farmers adopt on a sufficiently large extent without turning to mechanization, hired labor demand (and thus wages) will increase, and if widespread adoption on bigger farms increases aggregate food supply enough, rice prices will fall. This may disappoint those who want to have a direct impact, but the painful reality is that the poorest rural residents are commonly net food buyers and rely heavily on unskilled off-farm labor earnings (Weber et al. 1988, Barrett and Dorosh 1996, Reardon 1997). However, considering the high rates of disadoption among farmers who do not face liquidity problems, and the low extent of adoption among those who continue to practice the method, such aggregate effects seem unlikely at present in Madagascar.

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Table 1. Adopters and Disadopters of SRI for the Survey Sites

	Ambatovaky	Iambara	Torotosy	Anjazafotsy	Manandona	Average*
Percentage of households trying the method between 1993-99	48	16	27	28	21	25
Percentage of households using the method in 1999	26	7	0	13	17	15
Percentage of Adopters who "disadopted"	46	53	100	49	19	40

*Average is weighted to account for different numbers of households at each site

Table 2. Variable Descriptions

Variable	Definition	Choice
Education	Number of years of education of the household head.	All
Farmers' organization	Dummy variable indicating whether the farmer belongs to a farmer's group.	All
Agricultural day labor	Dummy variable equaling one if agricultural wages were a major source of income for the household.—considered a sign of poverty.	All
Stable income source	Income sources that are widely considered signs of relative wealth (salary, metalworking, and milk and wheat production) and is a dummy variable indicating one of these sources available to the household.	All
Distance to field	Average distance in minutes to the household's rice field.	Adopt, Disadoption
Distance between fields	Average distance in minutes between fields.	Extent, Disadoption
Number of adults	Number of adults in the household.	All
Number of children	Number of children in the household.	All
Female farmer	Dummy variable equaling one if the farmer is woman.	All
Age of the farmer	Age of farmer	All
Total lowland rice area	Number of ares of rice cultivated by the household.	All
Off-season cropping	Number of ares planted in winter crops on the rice fields.	All
Extension presence	Dummy variable equaling one if SRI extension services were available in the community during that year.	All
Past extension	Total number of years prior for which extension was available.	All
Use by other farmers	Sum of the proportion of area in SRI for all other farmers in the community for the previous year.	All
History of SRI	History of SRI use in the community, measured as sum of the proportion of area in SRI for all other farmers at least two years prior.	All
Experience	Sum of the area in SRI for all previous years for the farmer.	Extent and Disadoption
SRI farmers known	Dummy variable indicating whether the farmer knew other SRI farmers	Adopt
Receiving aid	Dummy variable referring to the whether the farmer received something (most often a mechanical weeder) in return for trying the method.	Extent and Disadoption
1996, 1997, 1998, 1999	Year specific dummy variables.	All

Table 3. Sample Selection Corrected Tobit Estimation Results (p-values in parentheses)

Explanatory Variable	Initial Adoption Decision First-Stage (Probit)	Extent of Adoption or Disadoption Second-Stage (Tobit)
Constant	-2.9419 (0.00000)	-0.1042 (0.32779)
Education	0.0439 (0.00028)	0.0045 (0.33249)
Farmers' organization	0.9195 (0.00000)	0.0536 (0.11471)
Agricultural day labor	-0.2801 (0.00594)	0.0410 (0.44259)
Stable income source	0.6604 (0.00000)	-0.0013 (0.96997)
Distance to field	-0.0003 (0.83856)	NA
Distance between fields	NA	-0.0027 (0.00357)
Number of adults	-0.0205 (0.30969)	0.0011 (0.89729)
Number of children	-0.0243 (0.17259)	0.0093 (0.24511)
Female farmer	0.0243 (0.84015)	0.0317 (0.47999)
Age of the farmer	-0.0045 (0.12480)	-0.0700 (0.53577)
Total lowland rice area	0.0035 (0.00006)	-0.0002 (0.52851)
Off-season cropping	0.0005 (0.84344)	0.0007 (0.22653)
Extension presence	0.8240 (0.00000)	0.1957 (0.00744)
Past extension	-0.0636 (0.30419)	0.0363 (0.13692)
Use by other farmers	10.446 (0.00003)	0.2885 (0.74825)
History of SRI	-35.346 (0.00000)	0.5121 (0.61303)
SRI farmers known	0.5260 (0.00711)	NA
Experience	NA	0.2303 (0.00000)
Receiving aid	NA	0.0974 (0.01443)
1999	3.4475 (0.00000)	-0.4073 (0.00029)
1998	2.0072 (0.00000)	-0.2365 (0.00022)
1997	1.1086 (0.00000)	-0.1380 (0.00838)
1996	0.3255 (0.00384)	-0.0655 (0.21600)
IMR	NA	0.1110 (0.0000)
	Percent Outcomes Correctly Predicted in Probit = 80 Pseudo R-squared for Probit: 0.73 N=1585	Percent of observations left-censored=25 Pseudo R-squared for Tobit: 0.86 N= 564

Table 4. Disadoption Probit Estimates
(p-values in parentheses)

Variable	Coefficient
Constant	-0.53062 (0.36277)
EEud Education	0.05277 (0.04817)
Farmers' organization	-0.11623 (0.45989)
Agricultural day labor	0.18885 (0.45638)
Stable income source	-0.65224 (0.00106)
Distance to field	0.00427 (0.31466)
Distance between fields	-0.00079 (0.92263)
Number of adults	0.03755 (0.40109)
Number of children	0.06604 (0.05239)
Female farmer	0.06653 (0.78966)
Age of the farmer	0.00583 (0.29242)
Total lowland rice area	0.00195 (0.24359)
Off-season cropping	0.00103 (0.87037)
Extension presence	0.27727 (0.39298)
Past extension	0.18941 (0.12132)
Use by other farmers	-2.9986 (0.57984)
History of SRI	2.5698 (0.62077)
Experience	0.43447 (0.00007)
Receiving aid	0.70310 (0.00107)
1999	-1.6854 (0.00282)
1998	-0.64454 (0.16978)
1997	-0.23209 (0.62598)
1996	0.21483 (0.66606)

Percent outcomes predicted correctly: 75
Pseudo R-squared: 0.57
N=418

Table 5. Joint Hypothesis Tests[23]

Effect	Adopt (Probit)		Extent (Tobit)		Disadoption (Probit)	
	$\times^2$ statistic	P-value	$\times^2$ statistic	P-value	$\times^2$ statistic	P-value
Liquidity	52.83	0.00	1.89	0.59	12.34	0.00
Labor	3.14	0.37	10.43	0.02	6.95	0.14
Learning	786.96	0.00	191.54	0.00	35.19	0.00
Learning from others	732.35	0.00	28.51	0.00	11.29	0.05
Social conformity	131.33	0.00	3.09	0.21	0.04	0.83
Year	403.05	0.00	15.83	0.00	16.34	0.00

[23] The joint hypothesis tests were conducted as follows: The liquidity effects variables are agricultural day labor, permanent income, and off-season cropping, and to test whether these variables have an effect on the dependent variables is equivalent to testing whether coefficients on these variable equal zero. The labor effects variables are the number of adults and children in the household and the distance to (or between) the rice fields. Learning from others is measured by the extension variables, community history of SRI use, and interactions with other (SRI) farmers through membership in a farmer's organization or personal knowledge. Learning by doing is measured by the farmer's experience with the method and his education. To distinguish the social effects from the learning effects, the joint tests of the former test whether there is a difference between the effects of current extension and past extension and between last season's community SRI use and that for all year's prior.

Table 6. Summary of Selected Econometric Results

Variable	Adopt	Extent	Continue
EduE Education	+	0	+
Membership in a Farmer's Organization	+	(+)	0
Agricultural day labor as a major source of income	–	0	0
Stable income source as a major source of income	+	0	–
Distance to or between fields	0	–	0
Total lowland rice area	+	0	0
Off-season cropping	0	0	0
Extension presence	+	(+)	0
Past extension	0	(+)	(+)
Other farmers' use of SRI the previous year	+	0	0
Historical use of SRI in the community	–	0	0
Farmer experience	NA	+	+
Receiving aid	NA	+	+
Joint Effects			
Liquidity	+	0	?
Labor	0	+	(+)
Learning	+	+	+
Learning from Others	+	+	+
Social Benefits	+	0	0

\+ indicates a significant positive effect,
(+) indicates a weakly positive effect
(siginifcant at the 15 percent level)

-- indicates a significant negative effect
0 indicates no significant effect

Figure 1. Percent of Households Adopting SRI Across Five Sites 1993-1999